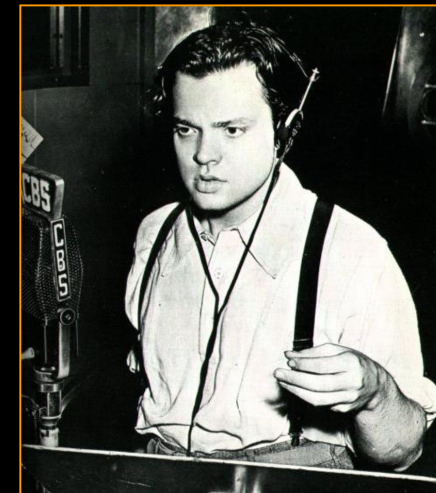
John D. Rummel
Margaret S. Race
Gerhard Kminek

The Development of Planetary Protection Requirements for Human Mars Missions: A History

March 24, 2015

In the beginning….

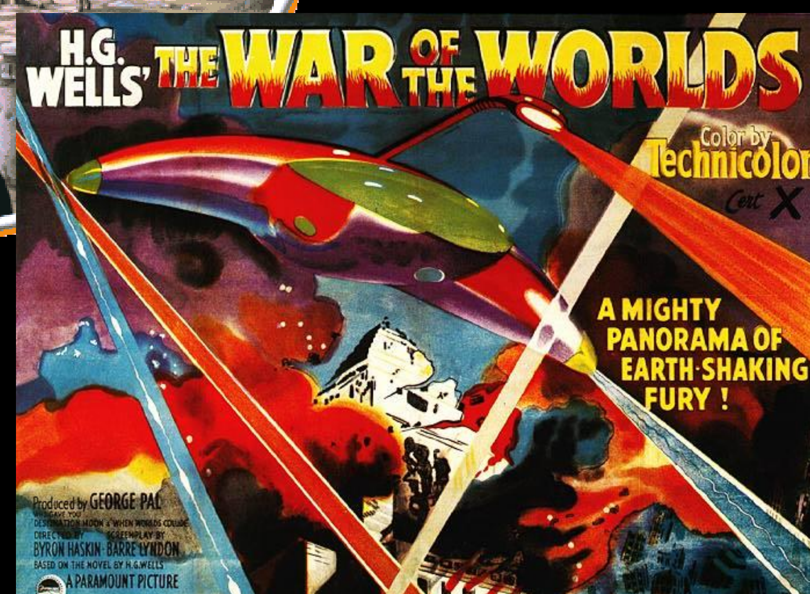
H.G. Wells
1898



Orson Welles
1938

"And scattered about...
were the Martians–dead!
–slain by the putrefactive
and disease bacteria against
which their systems were unprepared; slain as the red weed was
being slain; slain, after all man's devices
had failed, by the humblest things that God,
in his wisdom, has put upon this earth.

...By virtue of this natural selection of our kind
we have developed resisting power; to no
germs do we succumb without a struggle..."



Early Concerns: Protecting Science during Space Exploration

27 June 1958, Volume 127, Number 3313 SCIENCE

Moondust

The study of this covering layer by space vehicles may offer clues to the biochemical origin of life.

Joshua Lederberg and Dean B. Cowie

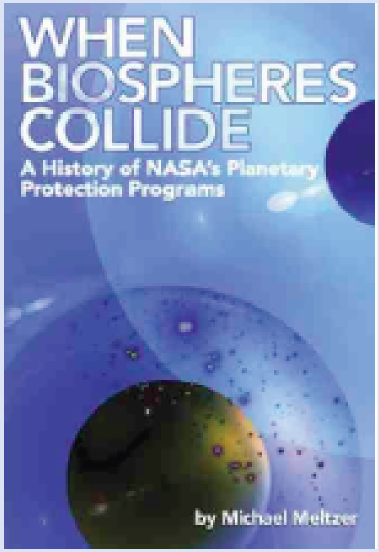
tions are very small, they are perhaps large enough to initiate the condensation. If this point is granted, it would then be necessary to examine the capture of a second atom of hydrogen or of carbon by the CH molecule. Because of the abundance of hydrogen, the first is more probable but the calculation of the probability of formation of the CH_2 molecule is very difficult. It is possible that some more hydrogen atoms attach themselves to the CH_2 molecule (CH, CH_3, CH_4 ?) but before long it is mainly atoms of much larger mass (C, N, O, . . .) which are captured because the large molecule

"...we urgently need to give some thought to the conservative measures needed to protect future scientific objectives on the moon and the planets"

Over 50 Years of International Effort

- 1956, Rome: International Astronautical Federation meets to discuss lunar and planetary contamination
- Feb. 1958: International Council for Science (ICSU) forms committee on Contamination by ExtraTerrestrial EXploration
- June 1958: NAS establishes the SSB
- July 1958: Formation of NASA
- July 1958: Formation of UN-COPUOS
- Oct. 1958: Formation of COSPAR by ICSU
- 1959-1962: Publication of guidelines:

  US, USSR, COSPAR



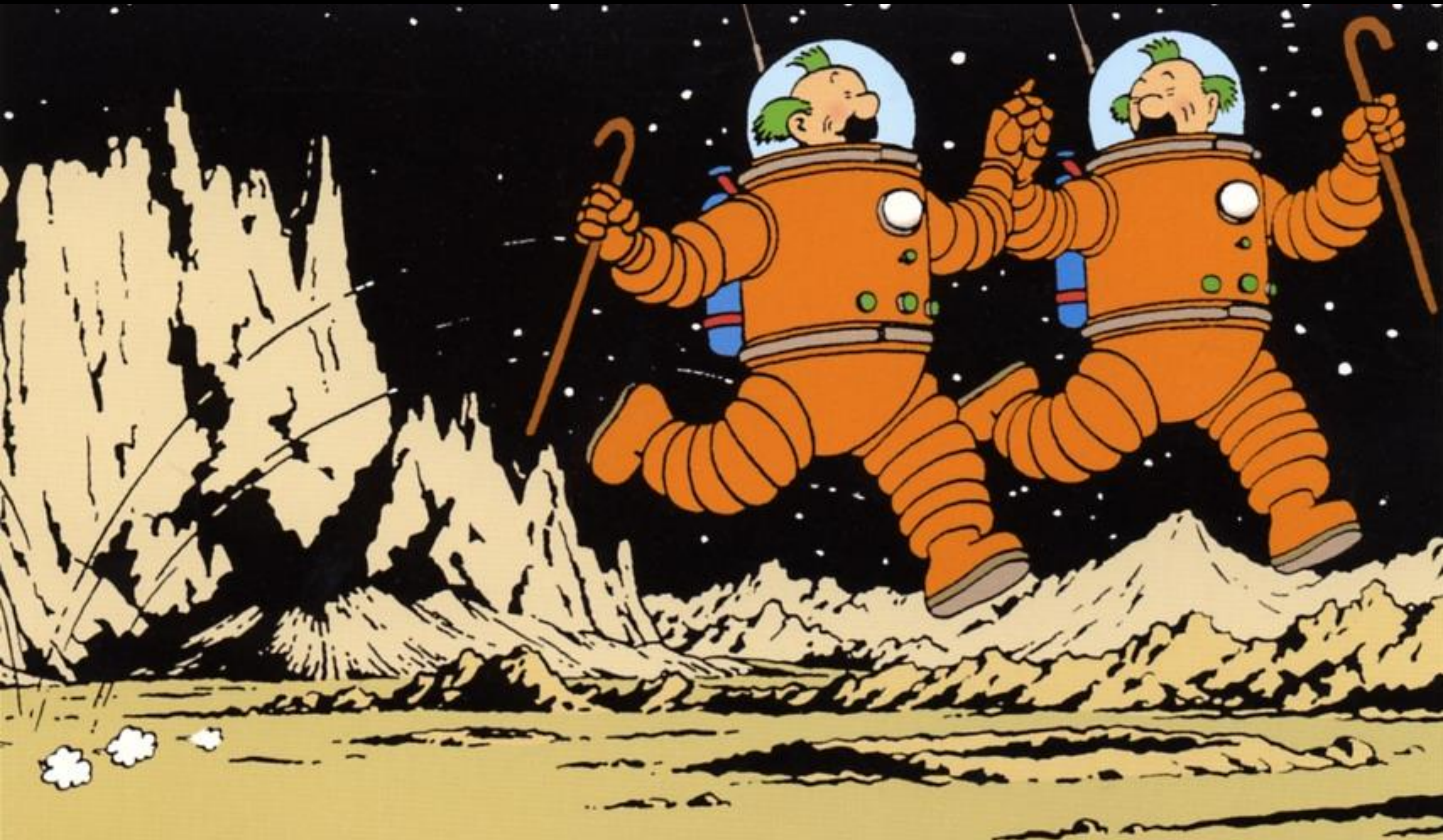
- 1963: NASA acquires the first 'Planetary Quarantine Officer' – on loan from the Public Health Service

International Agreements on Planetary Contamination/Protection

- The Outer Space Treaty of 1967:
  - Proposed to the UN in 1966
  - Signed by the US and Soviet Union in January 1967
  - Ratified by the US Senate on Apr. 25th, 1967
- Article IX:

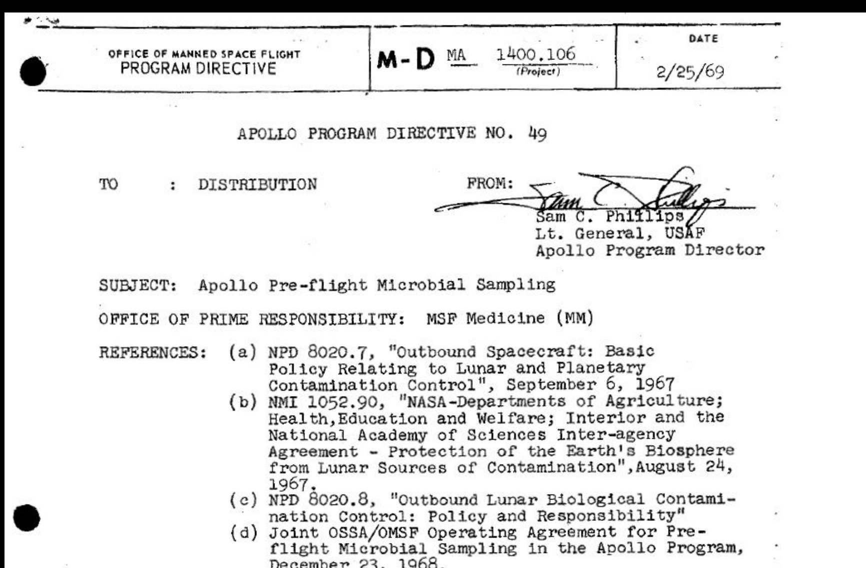
  "...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose..."

  "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."
  (http://www.state.gov/t/ac/trt/5181.htm)



Lunar Quarantine Activities in the Apollo Program

- Preflight biological sampling for
  - MSF medical needs for astronaut health
  - Back contamination evaluation requirement
  - Scientific needs (forward contamination record)
- Postflight (post lunar) quarantine of crew
  - 21 days after lunar module closure
  - Mobile quarantine facility (Airstream)
  - Lunar Receiving Laboratory at the MSC



OFFICE OF MANNED SPACE FLIGHT
PROGRAM DIRECTIVE

M-D MA 1400.106 (Project)

DATE 2/25/69

APOLLO PROGRAM DIRECTIVE NO. 49

TO : DISTRIBUTION

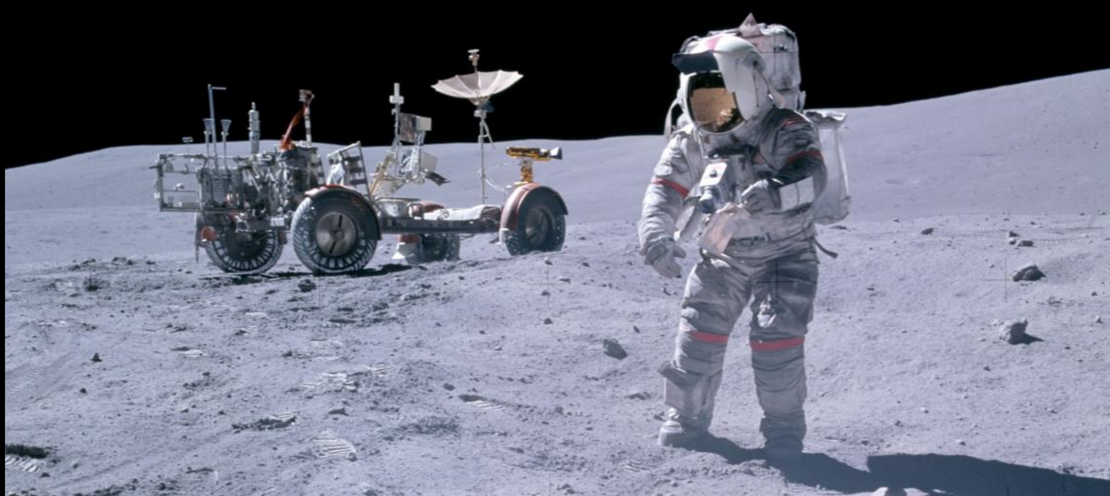
FROM: Sam C. Phillips
Lt. General, USAF
Apollo Program Director

SUBJECT: Apollo Pre-flight Microbial Sampling

OFFICE OF PRIME RESPONSIBILITY: MSF Medicine (MM)

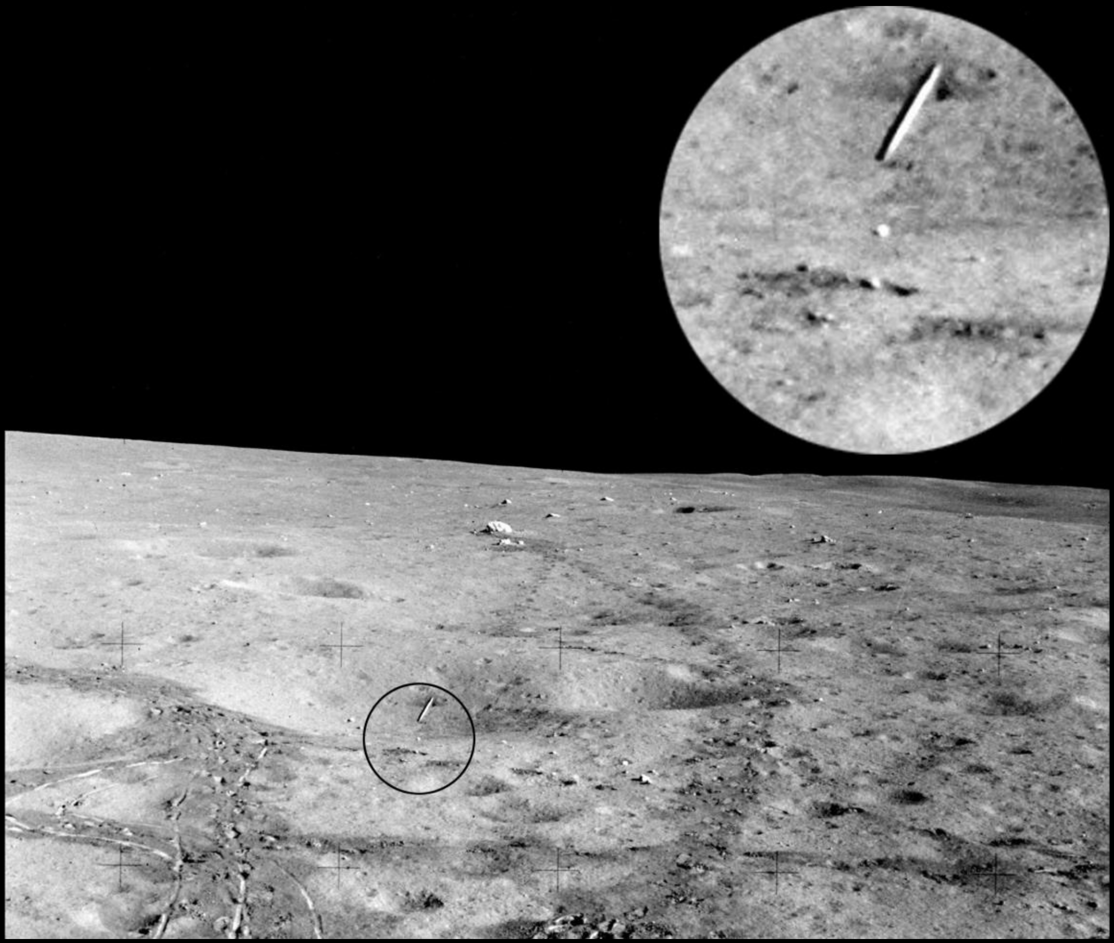
REFERENCES:
(a) NPD 8020.7, "Outbound Spacecraft: Basic Policy Relating to Lunar and Planetary Contamination Control", September 6, 1967
(b) NMI 1052.90, "NASA-Departments of Agriculture; Health, Education and Welfare; Interior and the National Academy of Sciences Inter-agency Agreement - Protection of the Earth's Biosphere from Lunar Sources of Contamination", August 24, 1967.
(c) NPD 8020.8, "Outbound Lunar Biological Contamination Control: Policy and Responsibility"
(d) Joint OSSA/OMSF Operating Agreement for Pre-flight Microbial Sampling in the Apollo Program, December 23, 1968.

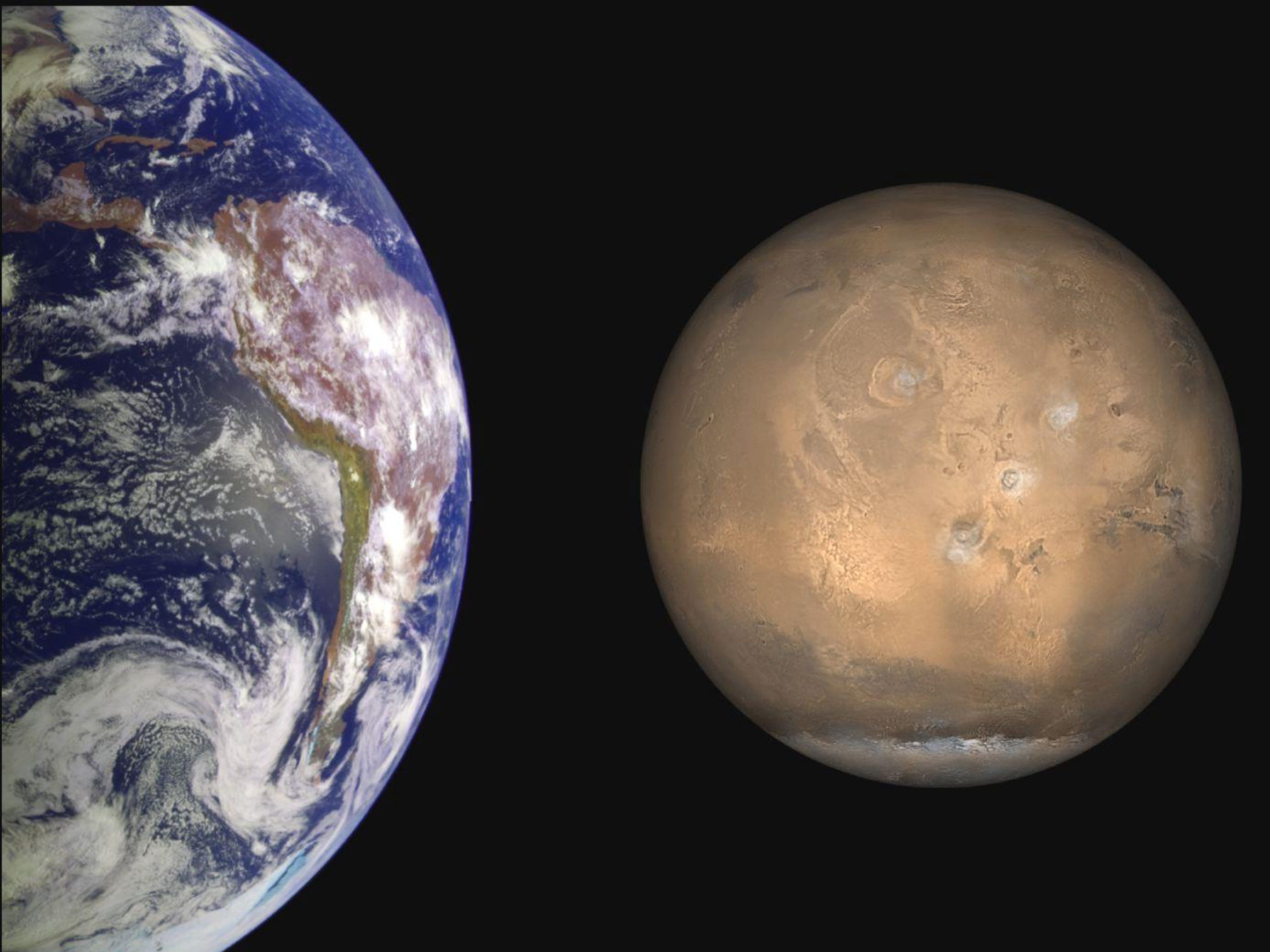
Lessons Can Be Learned from Apollo: Both Positive and Negative



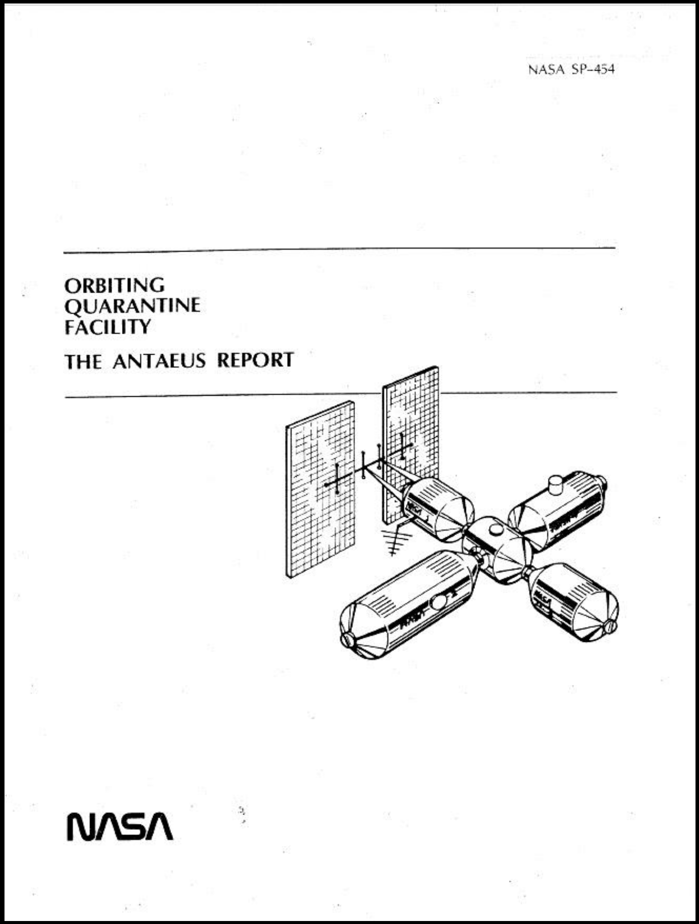
And there are still lessons left to learn!

Photo (AS14-66-9337) of the lunar surface taken during the Apollo 14 mission. The enlarged region contains one of the golf balls hit by Alan Shepard; next to the golf ball is the Solar Wind Collection mast thrown as a javelin by Edgar Mitchell. It is unlikely that any organisms remain on the top of these objects due to intense UV exposure, but what about the bottom side? Are there any organic compounds present?





Antaeus Report (1981)



- Result of 1978 NASA-ASEE Design Study
- First serious report on keeping a flight crew in contact with a part of Mars, while protecting them from contamination
  - “The design developed in this study provides crew protection that is at least equal to the protection afforded workers in existing terrestrial maximum containment facilities”
  - They were unaware of the long-term survival of Earth microbes in the space environment if protected from UV radiation
  - Unlike on Mars, such a facility will re-enter the Earth’s atmosphere if left untended
- “Data from experiments in which terrestrial organisms were exposed to simulated Martian conditions indicate that the terrestrial residents could survive on Mars and, if moisture were present, could even grow. Thus, although the Viking results indicate that life was not present at the lander sites in concentrations high enough to be detected by Viking instrumentation, samples were not taken in locales where life may be more likely to exist, such as more “tropical” regions, areas near the permafrost, and protected low areas.”

New NASA Planetary Protection Policy

NASA Procedures and Guidelines

NPG: 8020.12B

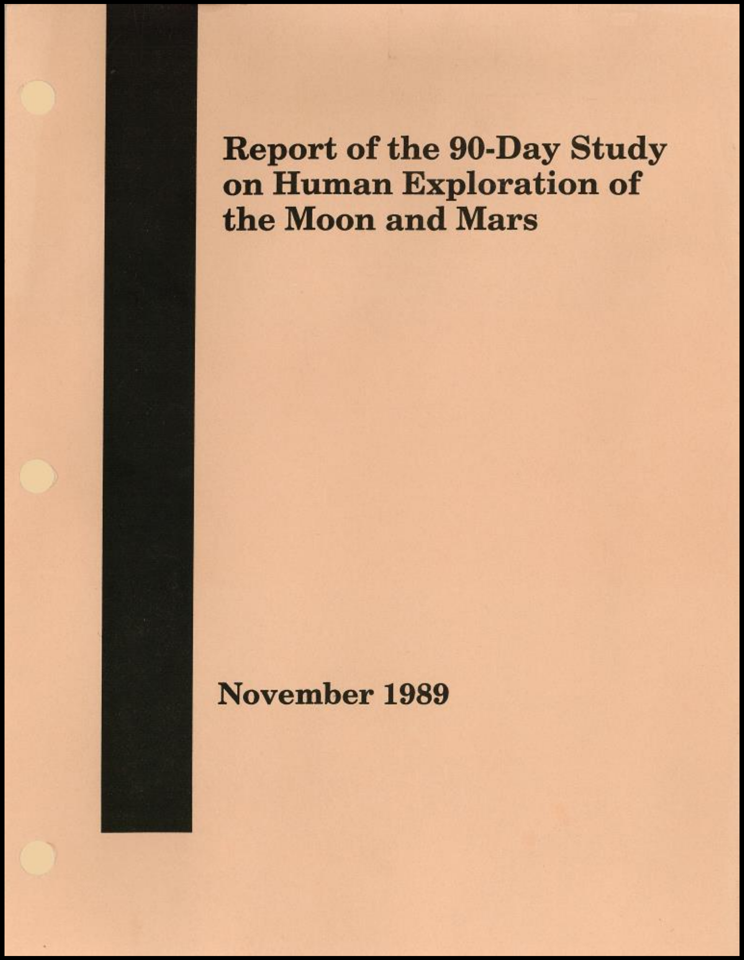
Effective Date: April 16, 1999
Expiration Date: April 16, 2005

Planetary Protection Provisions For Robotic Extraterrestrial Missions

Responsible Office: S/Space Science

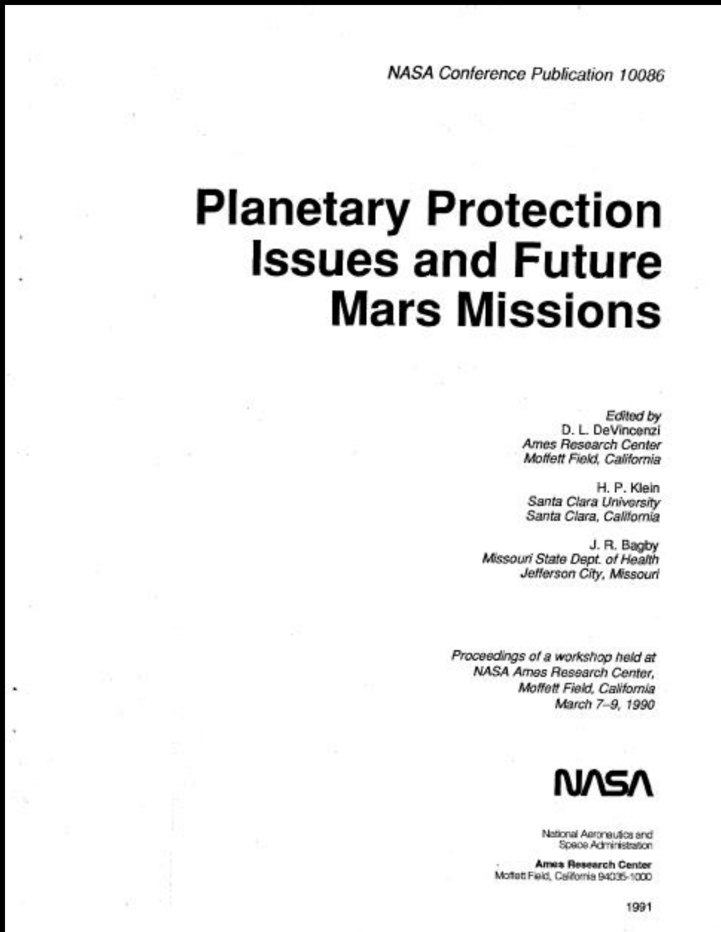
- Follows the COSPAR policy amended in 1984
- Implemented in Draft form in 1987
  - Galileo mission was initially implemented under the old policy, but the Challenger-induced change in the mission required a new PP Plan, and that was the first mission implemented under the new policy
  - Mars Observer was the second
- Finally approved by Ed Weiler as AA in 1999 (required me to return as PPO!)
- No mention of human missions in either the COSPAR or NASA policy

The 90-Day Study (1989)



- A response to a Presidential Initiative
- Heavily gamed by the DOE looking for a mission
- Mentions nothing of planetary protection or quarantine
- My fault!

Planetary Protection Issues and Future Mars Missions (1991)



NASA Conference Publication 10086

Planetary Protection Issues and Future Mars Missions

Edited by
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Moffett Field, California

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Santa Clara, California

J. R. Bagby
Missouri State Dept. of Health
Jefferson City, Missouri

Proceedings of a workshop held at
NASA Ames Research Center,
Moffett Field, California
March 7–9, 1990

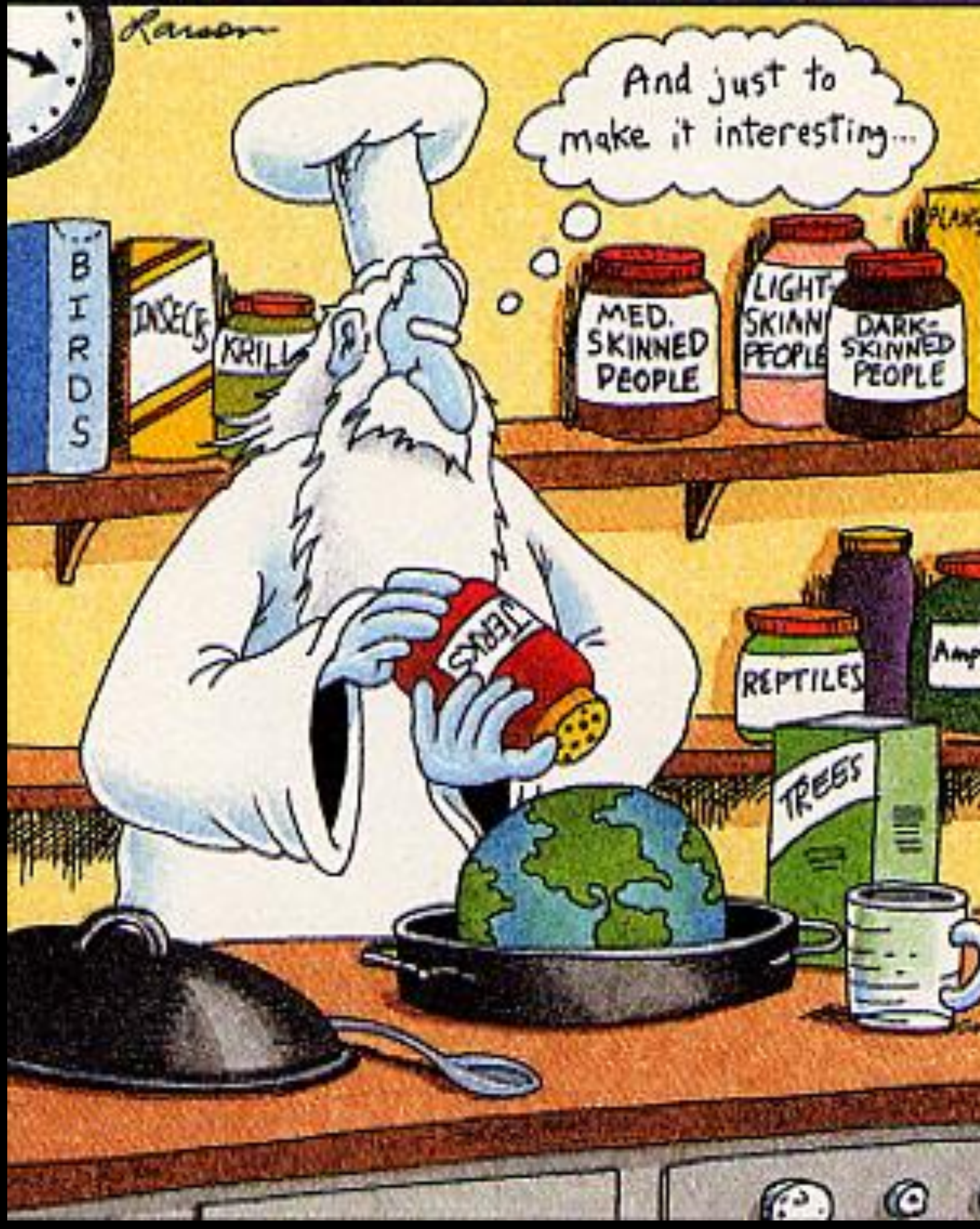
NASA

National Aeronautics and
Space Administration

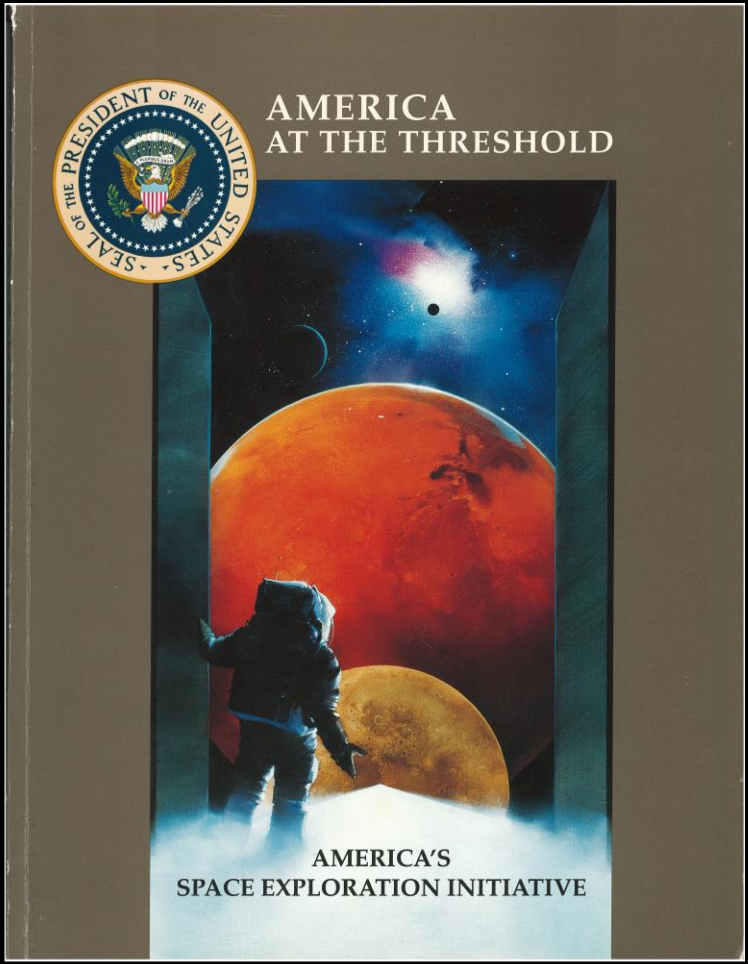
Ames Research Center
Moffett Field, California 94035-1000

1991

- Result of a Workshop held March 1990
- Focused on missions of the Space Exploration Initiative (SEI; G.H.W. Bush)
- Considered robotic precursors and results
  - “Detection of extant life during the precursor phase will undoubtedly cause a delay in human missions while the life-forms are characterized and their potential hazard and control are evaluated”
  - “It is recommended that biological and chemical contamination of Mars by human missions be minimized even if the results of precursor missions are negative with regard to extant life, since exobiological exploration for evidence of chemical evolution and past or present life is likely to be a continuing objective”
  - “The monitoring and characterization of any contamination of surface materials that may occur would also help preserve options for future scientific investigations”
  - “It is…recommended that precursor sample return missions include samples from sites representative of the future human landing sites”

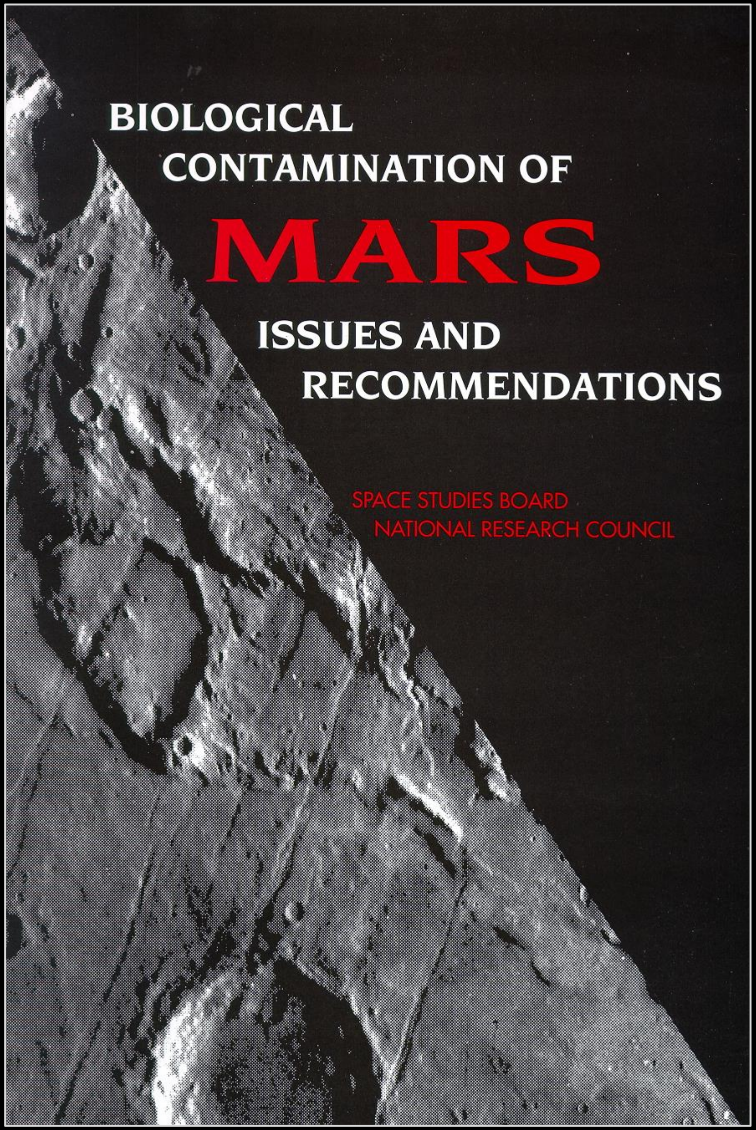

Larson
And just to make it interesting...
BIRDS
KRILL
MED. SKINNED PEOPLE
DARK-SKINNED PEOPLE
JERKS
REPTILES
TREES

The Synthesis Group (1991)



- A response to a Presidential Initiative as implemented for then Vice President Quayle by General Tom Stafford, et al.
- Approach to planetary protection was deeply flawed, and inserted into the document without review by the Group, *per se*:
  - Viking didn't find life on Mars
  - Therefore it's no big deal
  - But it is a long trip home to Earth
  - If somebody gets sick on the way home, we will deal with it at home
  - Q.E.D

Biological Contamination of Mars: Issues and Recommendations (1992)

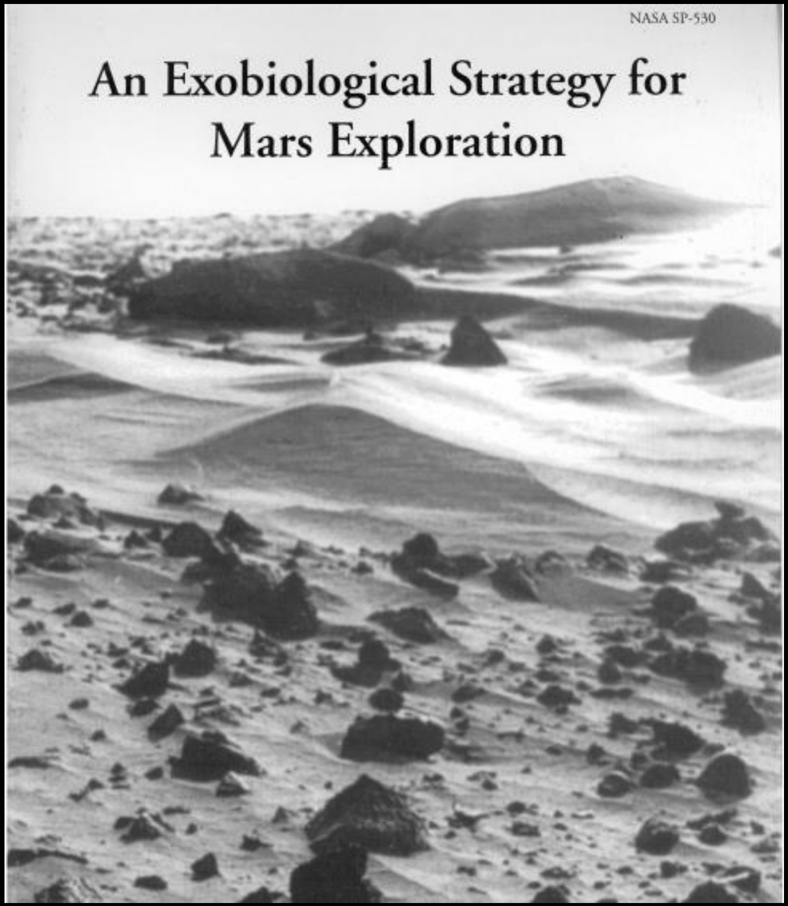


- NRC report requested in July 1990
- Focused on forward contamination issues
- Included “Recommendations Concerning Other Issues”

Piloted Versus Unpiloted Missions

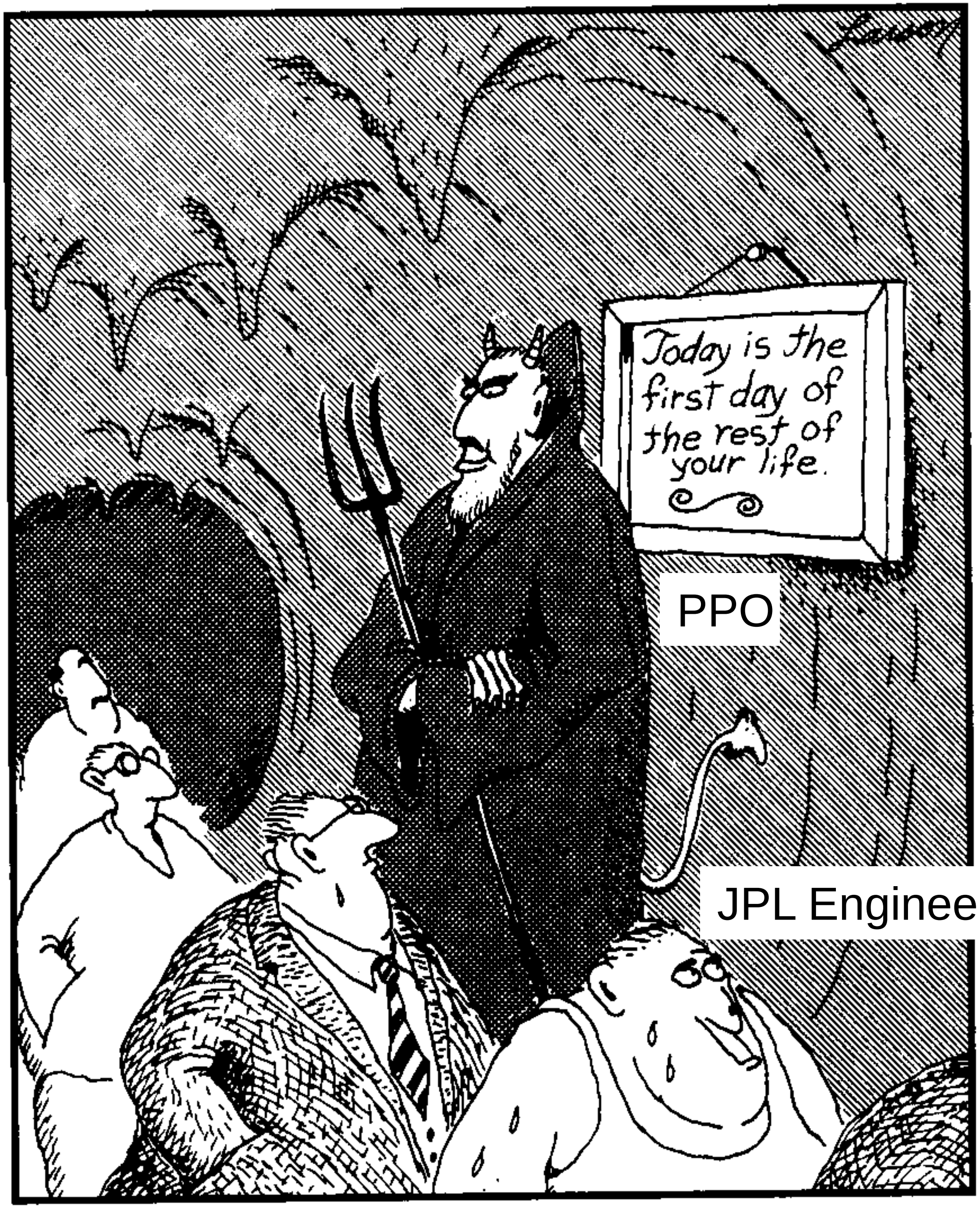
  – “Missions carrying humans to Mars will contaminate the planet. It is therefore critical that every attempt be made to obtain evidence of past and/or present life on Mars well before these missions occur. The issues of forward and back contamination have societal, legal, and international implications. These implications are serious, and they deserve discussion and attention.”

An Exobiological Strategy for Mars Exploration (1995)

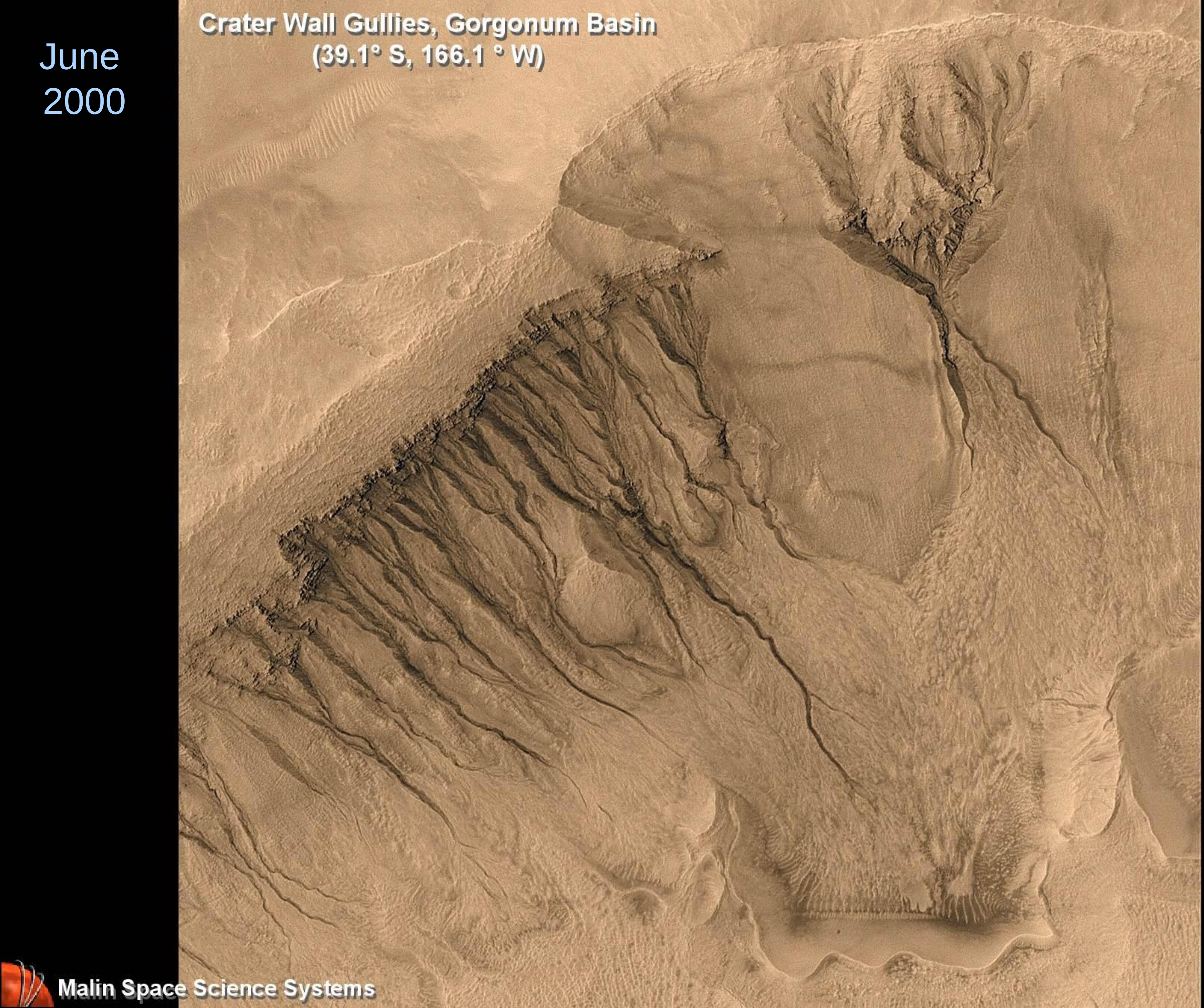


- Focused on new post-Viking strategy
- Considered plans for robotic missions leading to future human missions
  - “The fifth phase would involve human missions and would lead to establishment of a detailed geological context for any exobiologically significant observations made previously. Also, human presence would aid in the detection of "oases” capable of promoting or supporting life”
  - “Exobiology, in particular the search for extant and fossil ecosystems, is one of the few planetary science areas that may require human presence. The importance of field work in ecology and paleontology is well understood. Not all the tools for conducting field work robotically on another planet have yet been developed or proven. We strongly urge continuing development of such robotic techniques but recognize that it may be the case that a successful prosecution of the search for life-forms on Mars will ultimately require the active participation of life-forms from Earth.”

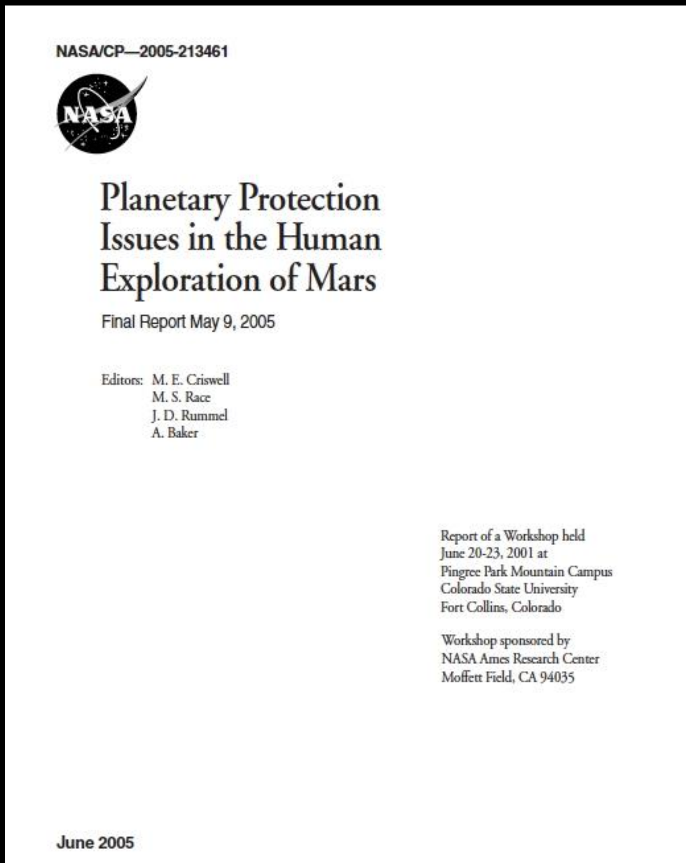
He’s baackkk….
November 1997



June
2000


Crater Wall Gullies, Gorgonum Basin
(39.1° S, 166.1 ° W)
Malin Space Science Systems

When Ecologies Collide? Planetary Protection Issues in the Human Exploration of Mars (June 2001)



NASA/CP—2005-213461

Planetary Protection Issues in the Human Exploration of Mars

Final Report May 9, 2005

Editors: M. E. Criswell
M. S. Race
J. D. Rummel
A. Baker

Report of a Workshop held
June 20-23, 2001 at
Pingree Park Mountain Campus
Colorado State University
Fort Collins, Colorado

Workshop sponsored by
NASA Ames Research Center
Moffett Field, CA 94035

June 2005

- Generally known as the ‘Pingree Park” workshop, with the primary question:
  – Can the human exploration of Mars be done effectively done without contaminating the planet?
- Three areas of concern:
  – Protecting Mars and Mars samples from forward contamination – “Protecting Mars
  – Protecting human health against risks from the Mars environment – “Protecting Human Health”, and
  – Preventing back contamination of Earth from samples and people returning from Mars – “Protecting Earth.”
- Consider: Can we do field science on Mars the way we do it on Earth?
  – Many feel that the answer is “Yes!”
  – An alternative view is that humans could be most effective teleoperating machines from the surface or orbit of Mars (“nearby”), while not depending heavily on EVA for science

Critical Aspects

1. Human capabilities in the scientific exploration of Mars
   Geology, geophysics, robotics, exobiology and human physiology

2. Protecting Mars and Mars samples from forward contamination, Earth to Mars

   Mitigation procedures and equipment for both precursor robotic and human missions

3. Protecting human health against risks from the Mars environment
   Hazards and consequences to human health from anticipated and unanticipated risks, control of exposure to risks during habitat occupancy and exploration operations

4. Preventing back contamination of Earth from Mars Return
   Sampling and return preparation on Mars, procedures upon mission return to Earth

5. Operations enabling a safe, productive human presence in the exploration of Mars
   Habitat design, support and exploration equipment, and operating procedures consistent with forward and back contamination control.

Pingree Park Results: Organization and Approach

Preserve operational capabilities of humans, assuming:

- Contamination concerns same as for robots
- First human mission => First complete 'Test'
- Identify major risk factors and possible mitigation

Related issues in:

- Human health
- Life support
- Work environment
- Psychological and performance factors
- "If Life, then what?"
  - Operational implications of different discovery scenarios
- Communications with the public
  - Responses to the discovery of ET life
  - Preparing the public for ET life—or not....

Pingree Park Results: Findings

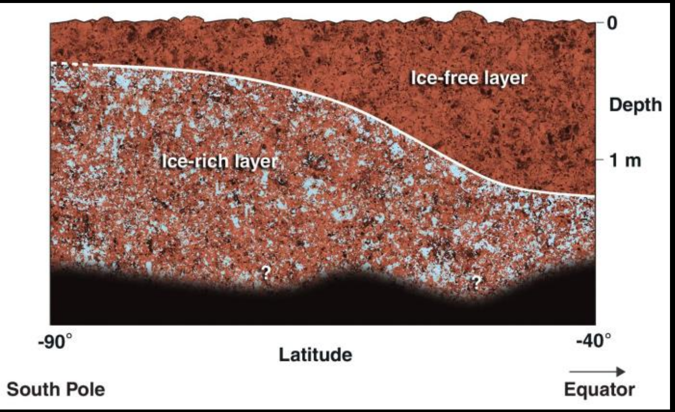
- Humans on Mars bring unique capabilities
- PP controls are critical in all mission phases
- Humans will bring contaminants
- Robotic precursor information is *essential*
- Nature of martian life, if any, is unknown
  - Possibly extreme or novel characteristics
- Initially, humans must be isolated from direct contact with Mars and martian materials

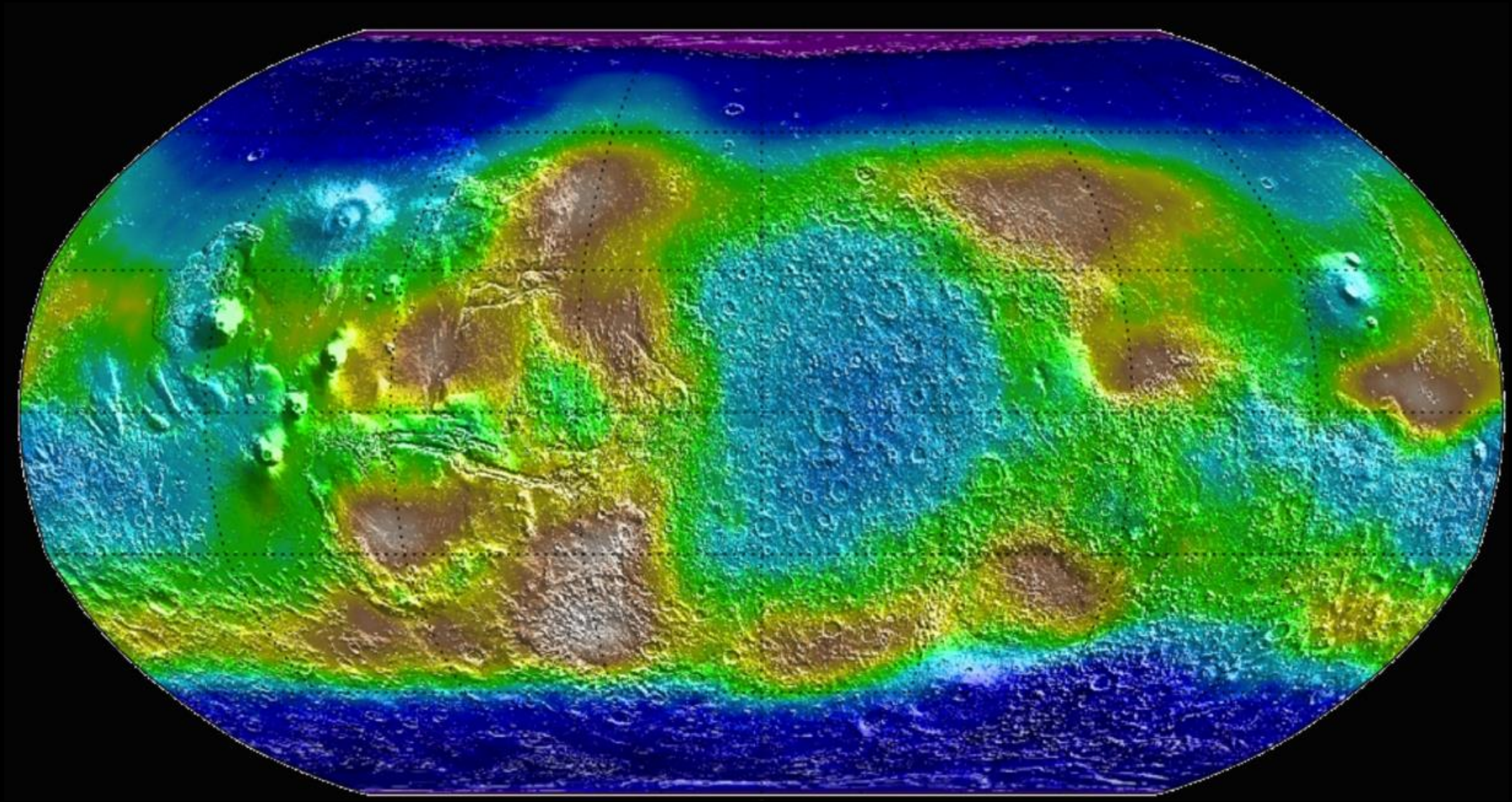
Pingree Park Results: Recommendations

- Need to categorize martian sites based on scientific interest and contamination concerns
- More study of forward contamination issues needed
  - Long-term Risks to Mars, effects of colliding ecologies, etc.
- Consider General Human Factors
  - Debilitation, reduced performance => unintended actions
- Improve technology and equipment for exploration, sampling, and base activities (including ingress / egress)
- Greatly improve subsurface sampling operations to limit contamination

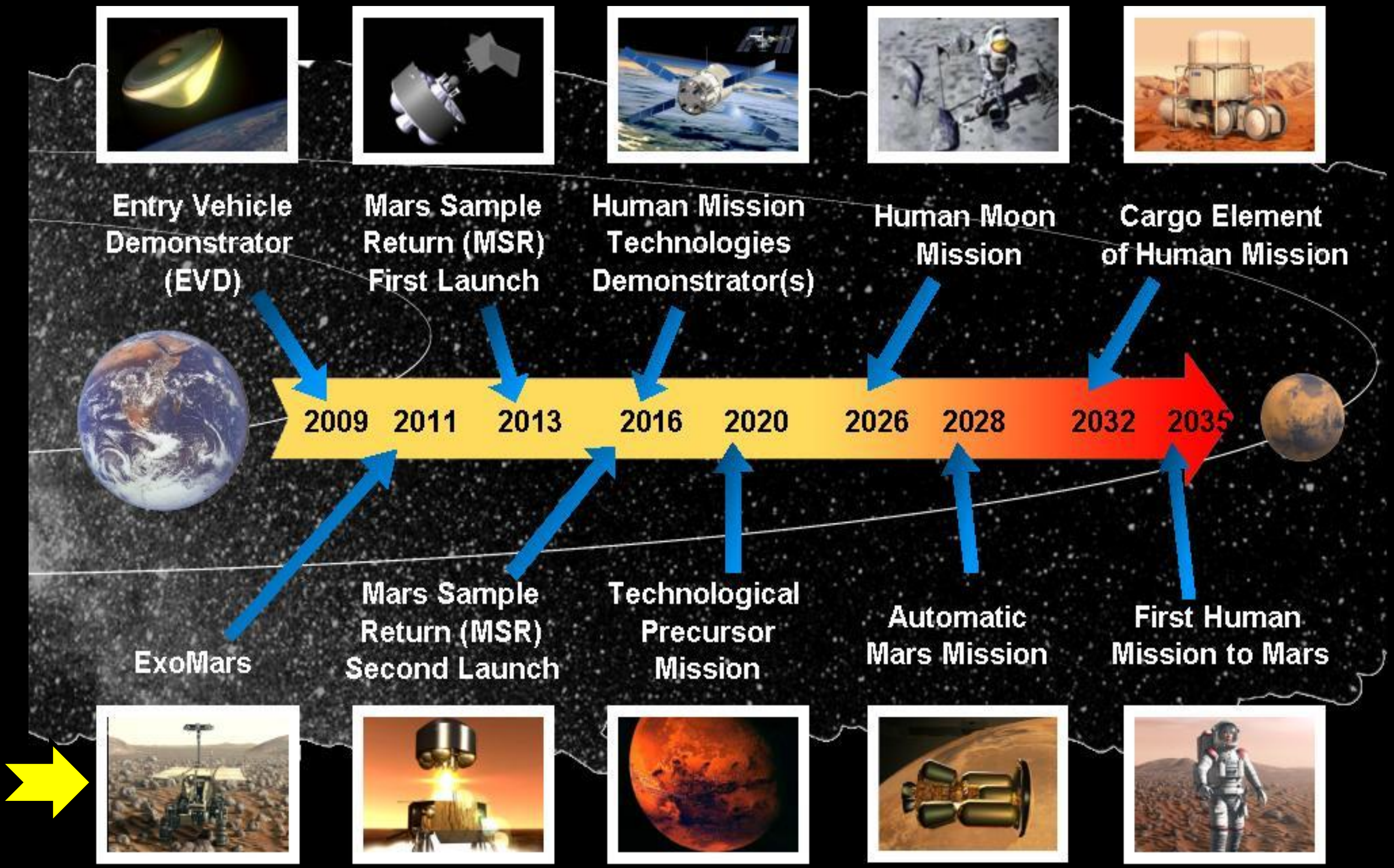
Mars Odyssey (2001)

- Thermal, epithermal, and fast neutron data from the GRS and HEND instruments indicate large quantities of hydrogen—interpreted as water ice—within the top meter of the martian surface, over a *wide* area.



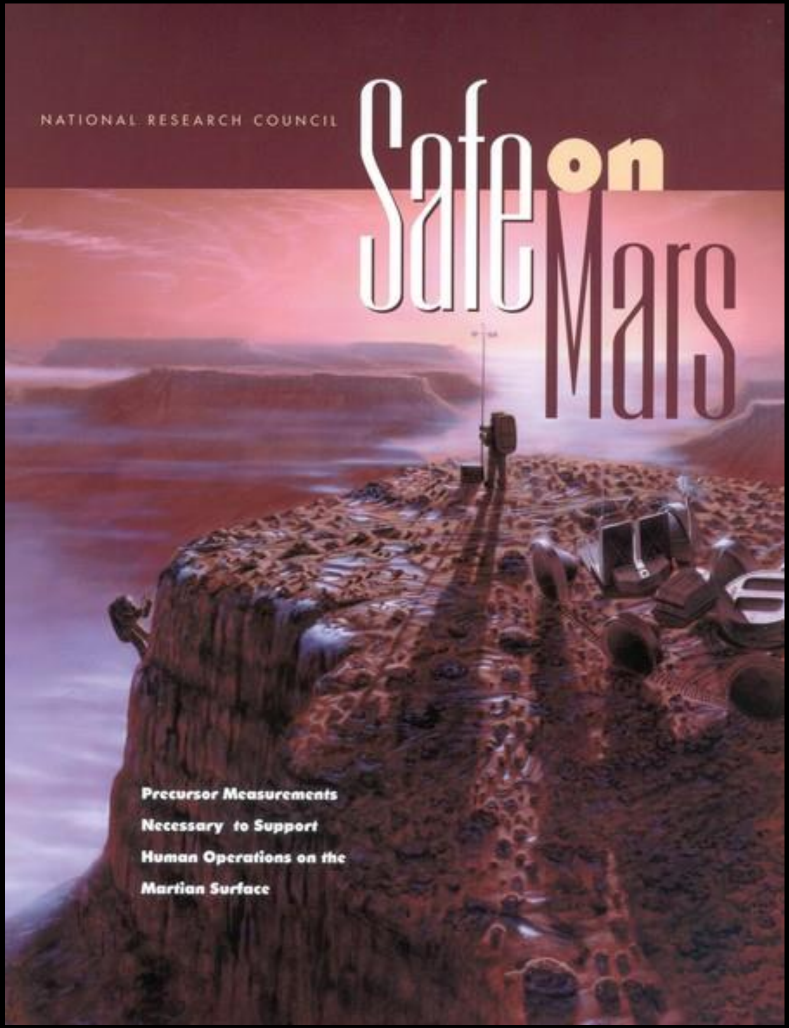


Aurora Mission Roadmap



Note: The NASA Exploration Initiative, announced in early 2004, provided new elements for further reflections on the content of the programme (Moon scenario)

Safe on Mars (2002)



- "Charged to "emphasize those technological issues which are directly relevant to managing environmental, chemical, and biological risks to humans operating on Mars"
- "Debate as to which agent, robot or human, is likely to reap the greatest rewards in the future exploration of Mars is outmoded and has evolved in the last decade into a discussion of how the two may complement each other"
- NASA "should establish the risk standards necessary to provide preliminary guidance to Mars mission planners and hardware designers."
- Committee also made recommendations regarding knowledge of the physical, chemical, and biological attributes of the Mars environment

Safe on Mars (cont.)

- The committee recommends that NASA establish zones of minimal biologic risk (ZMBRs) with respect to the possible presence of Martian life during human missions to Mars. In order to do so, NASA should conduct a precursor *in situ* experiment at a location as reasonably close to the human mission landing sites as possible to determine if organic carbon is present. The measurement should be on materials from the surface and down to a depth to which astronauts may be exposed. If no organic carbon is detected at or above the life detection threshold, the landing site may be considered a ZMBR. If no measurement technique can be used to determine if organic carbon is present above the life detection threshold, or if organic carbon is detected above that threshold, a sample should be returned to Earth for characterization prior to sending humans to Mars.
- “To prevent contamination of Earth by Martian material, great care must be exercised to ensure the containment of all material returned from Mars to Earth. There must be a sterile, intermediate transfer conducted in space that ensures Earth’s environment will not be exposed to any Martian material, including dust or soil deposits on the outside surface of the return vehicle. The protocols for such a sterile transfer will be complex and, if the transfer is unsuccessful, may require that the return vehicle be discarded in space and never returned to Earth. Ultimately, however, only contained materials should be transported back to Earth, unless sterilized first (NRC, 1997).”

Houston HRST/PP Workshop 2005:

- Presented by John A. Hogan

NASA/TM—2006-213485

Life Support and Habitation and Planetary Protection Workshop
Final Report

Editors:
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National Space Grant Foundation, NASA Ames Research Center, Moffett Field, California
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Jitendra A. Joshi and John D. Rummel
NASA Headquarters, Washington, DC

Prepared for the Life Support and Habitation and Planetary Protection Workshop
Held at the Center for Advanced Space Studies
Houston, Texas, April 27-29, 2005
Sponsored by NASA Headquarters

MAY 2006


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THE PLANET
IS EVERYONE'S
JOB.
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WE AGREE.
Harry Butler
Dr Harry Butler
Australian Naturalist
Russell Lagdon
Russell Lagdon
Environment Manager
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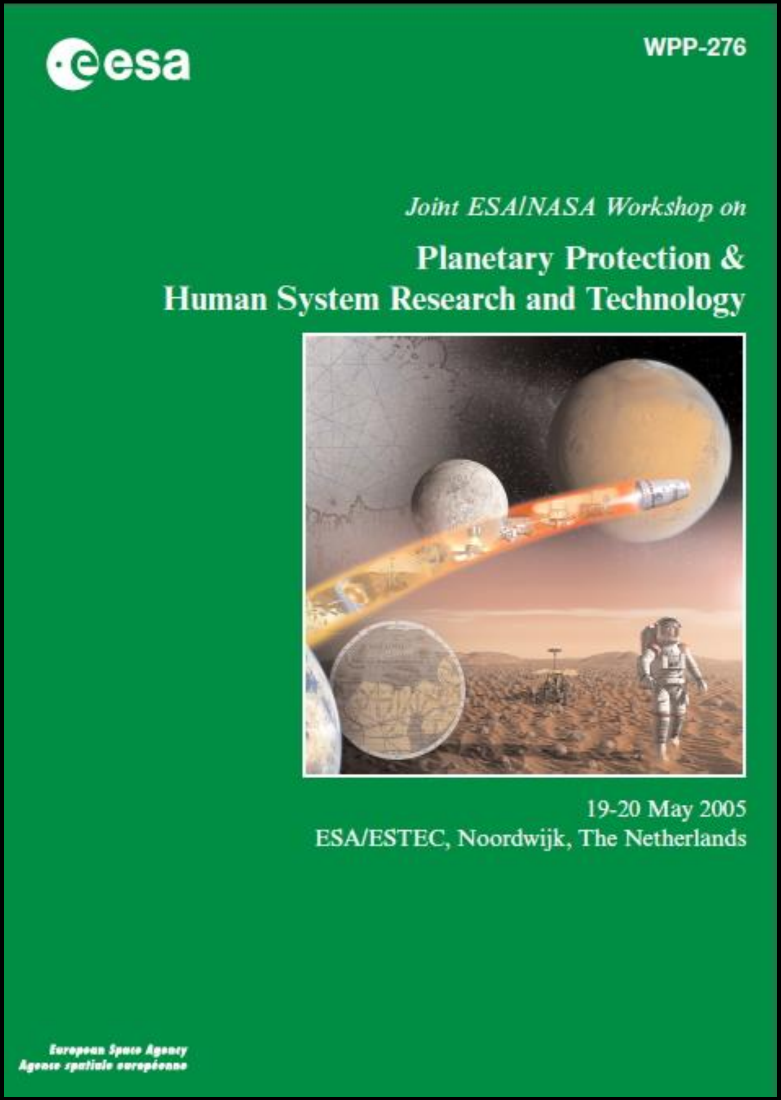
ESA-NASA Workshop (2005)



- Goals of the Workshop
  - Initiate communication, understanding and a working relationship among the ALS, EVA, and PP communities in NASA and ESA.
  - Identify knowledge necessary to establish PP requirements wrt ALS and EVA systems, including the identification of potential contaminants, contamination pathways, and potential off-nominal events typical of such systems.
  - Explore operations and technology issues concerning the potential disruption of an extraterrestrial ecology via EVA and/or ALS operations, including interplanetary and planetary surface waste disposal, etc.

ESA-NASA Workshop (cont.)

- Goals of the Workshop (cont.)
  - Explore the requirements posed by the astrobiological/geological exploration of Mars, and examine how EVA and ALS systems may affect them.
  - Examine how ALS and EVA systems interact with back-contamination prevention requirements to protect both the human habitat on Mars and the Earth upon crew return.
  - Identify future research needs for ALS, EVA, and Mars robotic-missions, and define precursor mission requirements to understand and prepare for human support systems for a Mars mission.

ESA-NASA Workshop Organization

- Agenda
  - Half day of Mars background and PP requirements
  - 1.5 days of intensive discussion on Mars requirements for robotic missions and their heritage
  - This workshop conducted during the period of May 19-20, 2005 at the European Space Research and Technology Centre, Noordwijk, Netherlands
- Groups
  - Advanced Life Support (ALS) Group
    - » C. Lasseur and M. Kliss (Co-chairs), K. Buxbaum, R. Fisackerly, P. Heeg, S. Hoffman, R. Lindner, P. Mani, J. A. Spry, P. Stabekis
  - Extravehicular Activity (EVA) Group
    - » J. Kosmo (Chair), D. Beaty, A. Debus, C. McKay, D. Andersen, S. Hovland, G. Kminek
  - Operations (Ops) Group
    - » B. Ward (Chair), B. Clark, D. Eppler, G. Horneck, M. Race, F. Raulin, J. Rummel

ESA/NASA Workshop (May 2005): Ops Group Recommended Planetary Protection Requirements for Humans on Mars

Assumptions

- The greater capabilities of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood.
- It will be not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems.
- Crewmembers exploring Mars will inevitably be exposed to martian materials. To the maximum extent practicable, these exposures should occur under controlled conditions.
- Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration.

Overall Policy Requirements (Level 0)

- Planetary protection shall be considered a critical element for the success of human missions to Mars
- Evaluation of planetary protection requirements shall be considered in all human Mars mission subsystems development
- Planetary protection considerations shall be included in human Mars mission planning, training, operations protocols, and mission execution.

Conceptual Approach

- Human missions to Mars shall not affect or otherwise contaminate "special regions" of Mars, nor be contaminated by materials from them
  - Mission cleanliness and containment requirements shall avoid the inadvertent introduction of Earth organisms or organic molecules into these environments, and the inadvertent exposure of human explorers
  - Landing site selection and operational accessibility to scientifically desirable special regions (including prime access to ISRU-important subsurface ice or water) shall be traded against the microbial or organic cleanliness of human-associated (or robotic) systems
- Calculations based on this approach will determine the allowable levels and kinds of contamination allowed for specific aspects of any particular human mission.

Definition of “Special Region”

A Special Region is defined as a region within which terrestrial organisms are likely to propagate,

OR

A region which is interpreted to have a high potential for the existence of extant Martian life forms.

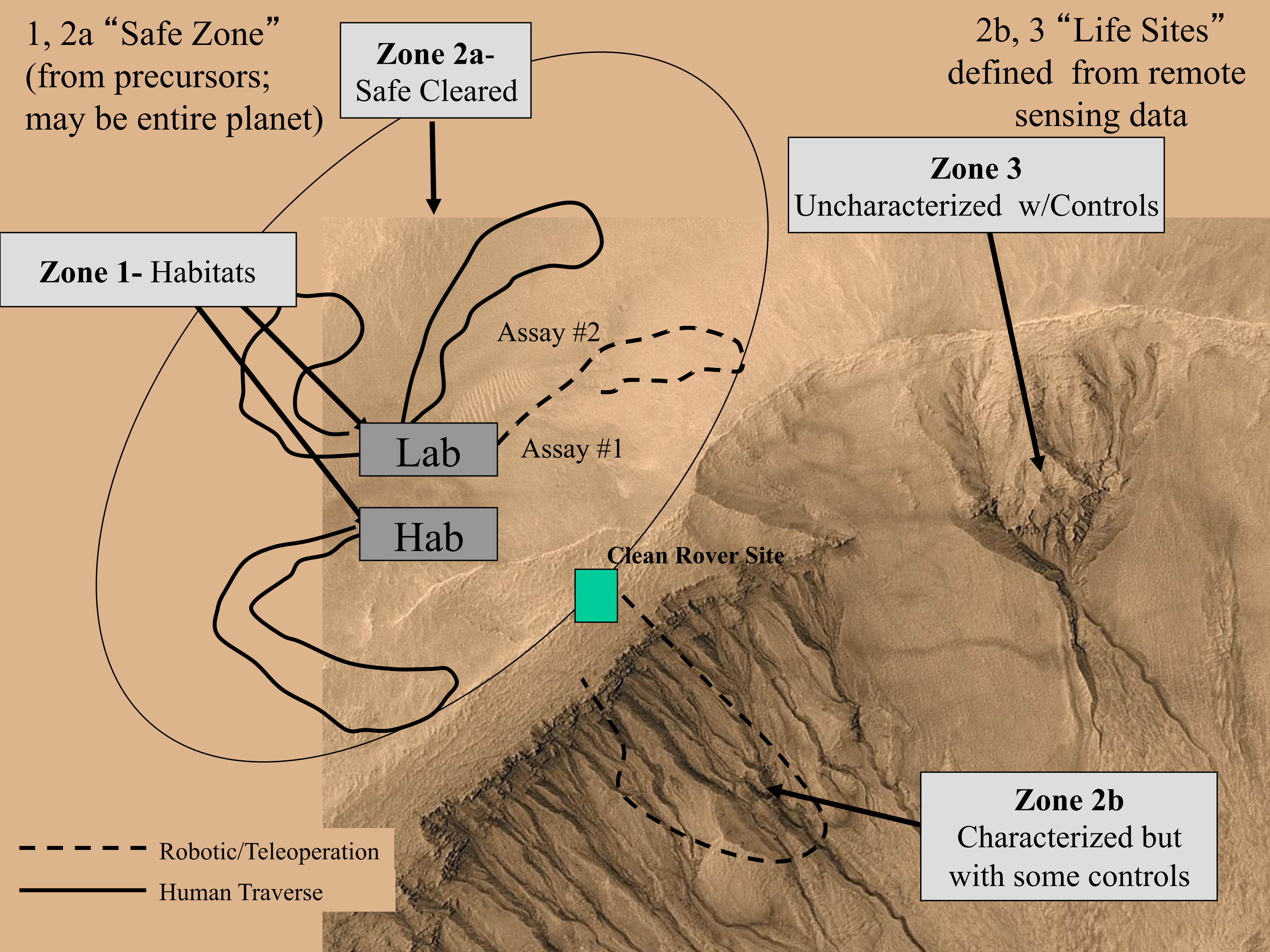
Think liquid water, at a temperature to support life

PP General Issues

1. Planetary protection risks are among the many risks to be identified and evaluated together—then reduced, mitigated, or eliminated when possible to enable mission success.

2. General human factors need to be considered along with planetary protection issues for a human mission to Mars.

3. A crewmember onboard the mission should be given primary responsibility for the implementation of planetary protection provisions affecting the crew during the mission.


1, 2a "Safe Zone"
(from precursors;
may be entire planet)
Zone 2a-
Safe Cleared
2b, 3 "Life Sites"
defined from remote
sensing data
Zone 3
Uncharacterized w/Controls
Zone 1- Habitats
Assay #2
Lab
Assay #1
Hab
Clean Rover Site
Zone 2b
Characterized but
with some controls
Robotic/Teleoperation
Human Traverse

Forward Contamination Control

Additional development and design is needed to characterize exploration, sampling, and base activities to assure effective operations and the required level of planetary protection control

- Processes associated with EVA egress/ingress must be characterized and optimized
- An inventory of microbial populations (and organics) carried aboard and potentially released by human-associated spacecraft and suits should be established and maintained in support of both planetary protection and crew-health objectives
- Systems should be provided to allow controlled, aseptic, subsurface sampling operations, so that uncontaminated samples can be returned to the surface, and so that human-associated contaminants are not introduced to the subsurface.

Backward Contamination

[Short loop] Operations of a human mission to a new site shall include isolation of humans from directly contacting martian materials until initial testing (either precursor-mission or on-mission robotic testing) can provide a state-of-the-art verification of the landing site as a "zone of minimum biological risk" (per the NRC recommendation in *Safe on Mars* [2002]).

Exploration, sampling, and base activities should be accomplished in a manner to limit inadvertent exposure to the subsurface or to otherwise-untested areas of Mars

- A means for allowing controlled access to those areas shall be provided.

Backward Contamination (cont.)

A quarantine capability for both the entire crew and for individual crewmembers shall be provided during and after the mission, in case potential contact with a martian life-form occurs

- As part of normal crew health monitoring and in support of the assessment of possible quarantine measures, basic tests of the medical condition of the crew and their potential response to pathogens or adventitious microbes shall be defined, provided, and employed regularly on the mission.
- A quarantine capability and appropriate medical testing shall be provided for the crew upon return to the Earth (Moon or Earth-orbit) and if necessary, implemented in conjunction with a health monitoring and stabilization program.

Backward Contamination (cont.)

[Long Loop] Samples returned by the crew from uncharacterized or otherwise-untested areas of Mars shall be considered as potentially hazardous, and shall not be released from containment unless they are subjected to a sterilizing process, or until a series of tests determines that they do not present a biohazard.

Off-Nominal Events to be Worked/Tested in Appropriate Testbeds

- Crash of cargo or human carrying vehicle, or a subset of spacecraft-carried material (jettison)
- Fire in habitat suppressed by depressurization, or other factors resulting in breach of habitat integrity
- Tear or other failure in EVA system
- Partial failure of ALS system or critical components
- Waste containment/filtering breach
- ISRU recovery contamination event
- Nuclear-power system thermal containment effects/breach
- Other power-system failure (battery leakage, fuel cell degradation/failure, tank explosion…)
- Breach of pressurized rover

Amelioration of Planetary Protection effects involves site identification, documentation of incident, and possible remediation of localized contamination

Basis for Current Policy Framework

- The ESTEC workshop (as the sum of the previous workshop reports and recommendations) developed guidelines for review by the agencies and planetary exploration communities.
- The refined guidelines were subsequently communicated to COSPAR
- They were accepted at the biannual assembly in 2008 as part of COSPAR’s policy by the Panel on Planetary Protection and recommended to the COSPAR Bureau and Council

Planetary Protection Panel Resolution wrt Planetary Protection and the Human Exploration of Mars

COSPAR

Noting that:

- the continuing scientific exploration of Mars is a compelling subject for international mission planning and Mars is the site of continuing discovery; and
- an important goal of Mars exploration is to address questions related to organic chemical evolution and the origin of life; and
- future human missions can contribute to answering those questions only if they conform to COSPAR's planetary protection goals;

and noting that

- both NASA and ESA have conducted several workshops on this subject (Pingree Park, 2001; Houston, 2005; Noordwijk, 2005) working with a broadly interdisciplinary group of scientists and engineers, including operations personnel and medical staff, and their summary recommendations have been evaluated and accepted by the COSPAR Workshop on Planetary Protection (Montreal, 2008);

COSPAR therefore:

- includes the following section on principles and guidelines for Human Missions to Mars within its revised Planetary Protection Policy (date TBD):

New:

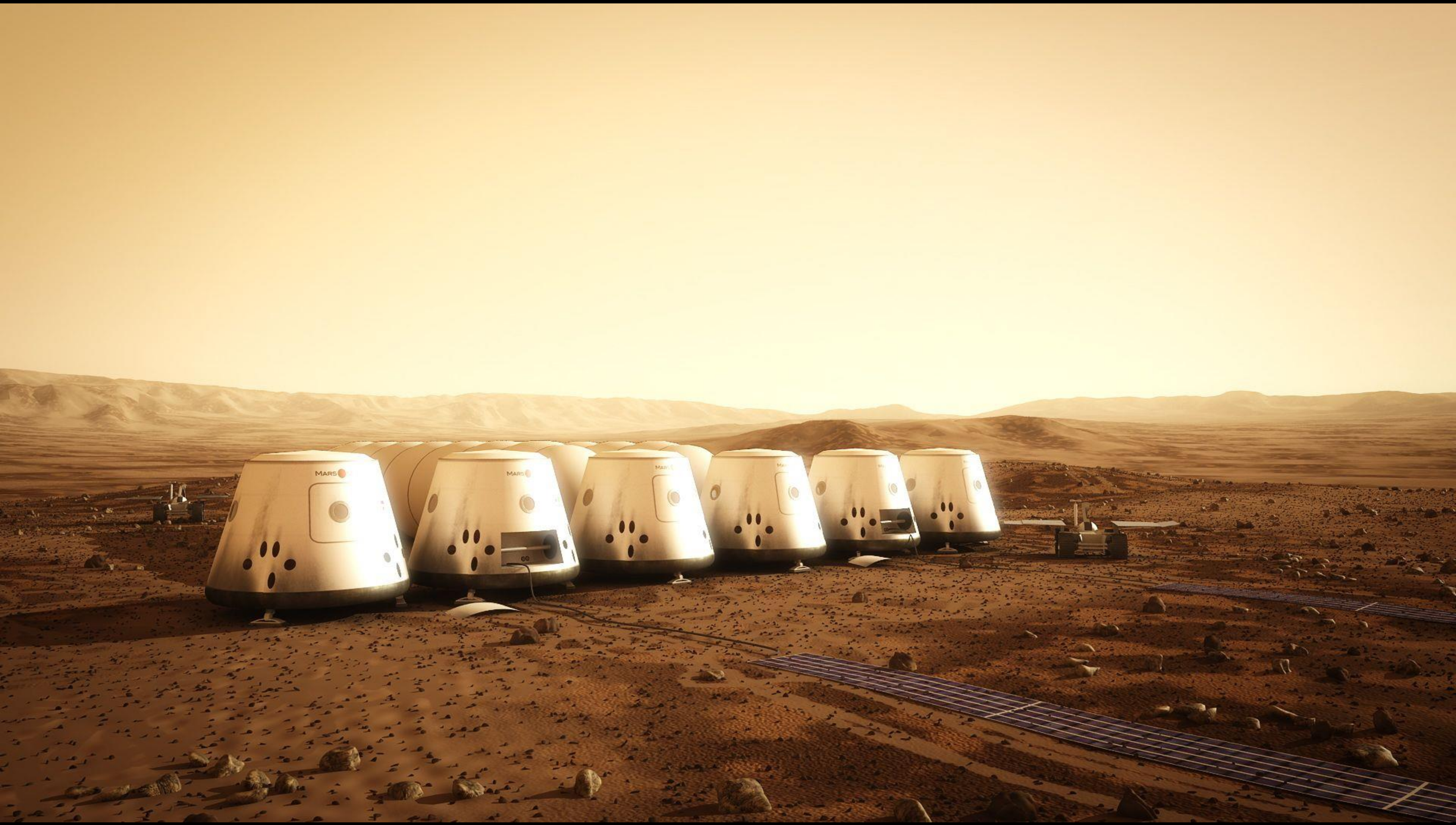
Principles and Guidelines for Human Missions to Mars

The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, planetary protection goals should not be relaxed to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions—even if specific implementation requirements must differ. General principles include:

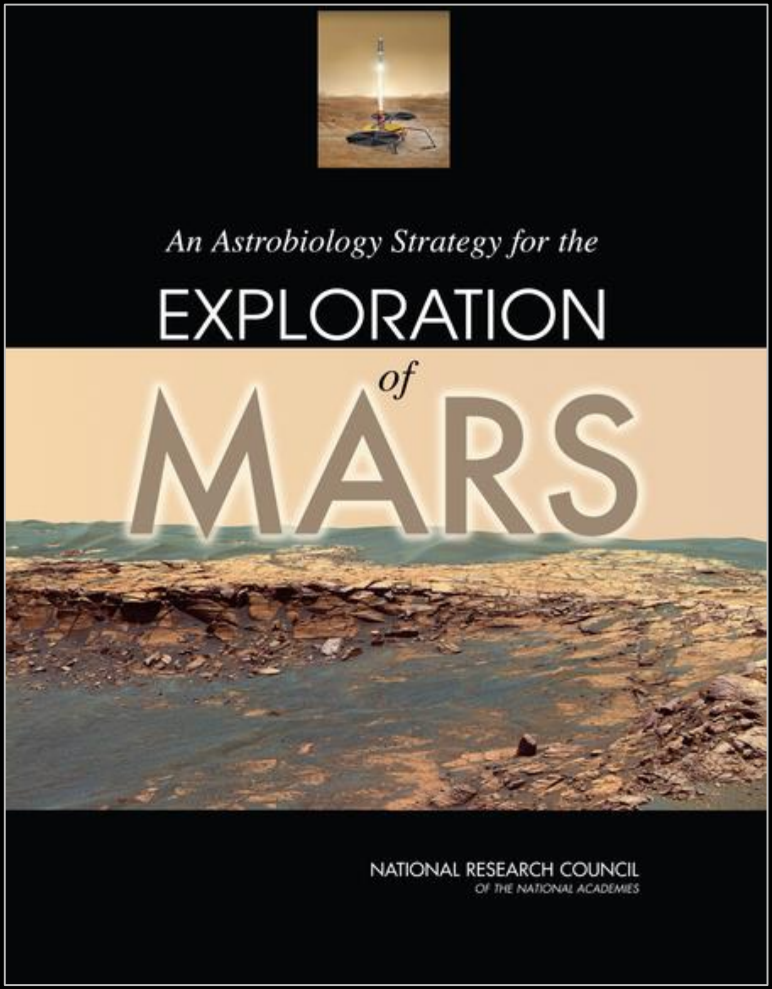
- Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration.
- The greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood.
- For a landed mission conducting surface operations, it will not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems.
- Crewmembers exploring Mars, or their support systems, will inevitably be exposed to martian materials.

In accordance with these principles, specific implementation guidelines for human missions to Mars include:

- Human missions will carry microbial populations that will vary in both kind and quantity, and it will not be practicable to specify all aspects of an allowable microbial population or potential contaminants at launch. Once any baseline conditions for launch are established and met, continued monitoring and evaluation of microbes carried by human missions will be required to address both forward and backward contamination concerns.
- A quarantine capability for both the entire crew and for individual crewmembers shall be provided during and after the mission, in case potential contact with a martian life-form occurs.
- A comprehensive planetary protection protocol for human missions should be developed that encompasses both forward and backward contamination concerns, and addresses the combined human and robotic aspects of the mission, including subsurface exploration, sample handling, and the return of the samples and crew to Earth.
- Neither robotic systems nor human activities should contaminate "Special Regions" on Mars, as defined by this COSPAR policy.
- Any uncharacterized martian site should be evaluated by robotic precursors prior to crew access. Information may be obtained by either precursor robotic missions or a robotic component on a human mission.
- Any pristine samples or sampling components from any uncharacterized sites or Special Regions on Mars should be treated according to current planetary protection category V, restricted Earth return, with the proper handling and testing protocols.
- An onboard crewmember should be given primary responsibility for the implementation of planetary protection provisions affecting the crew during the mission.
- Planetary protection requirements for initial human missions should be based on a conservative approach consistent with a lack of knowledge of martian environments and possible life, as well as the performance of human support systems in those environments. Planetary protection requirements for later missions should not be relaxed without scientific review, justification, and consensus.


MARS

An Astrobiology Strategy for the Exploration of Mars (2007)



- Intended as "an up-to-date integrated astrobiology strategy for Mars exploration that brings together all the threads of this diverse topic"
- "Current astrobiology science goals for the exploration of Mars can be addressed via a series of robotic spacecraft missions in the near- to mid-term future. It is critical that any astrobiological evidence that might be present on Mars not be compromised by robotic or human activities before definitive measurements or sample return occur."

Finding. "The scientific study of Mars, including return to Earth of astrobiologically valuable samples that can be used to address the questions being asked today, can be done with robotic missions."

MEPAG P-SAG Report

MEPAG P-SAG Team

(Humans to the Martian System Summary of Strategic Knowledge Gaps; 2012)

- Identify knowledge needed prior to human missions to ensure planetary protection requirements are met during mission implementation.
  - Protection of Mars
    - Avoid contamination of Mars by terrestrial organisms and organics until definitive life detection experiments are performed and any life detected is characterized
  - Protection of Earth
    - Ensure that martian materials returned to Earth are contained until they are shown to be safe
  - Protection of crew
    - Ensure that exposure to martian materials does not present a hazard to the crew

MEPAG P-SAG on Forward Contamination

MEPAG P-SAG Team

- **SKG's**
  - Do not know whether Mars has or ever had any indigenous life, and if it had, what its characteristics are.
  - Do not know whether there are locations at or near the surface that are hospitable to terrestrial life, and if so where those locations are
  - Do not know the extent to which terrestrial contaminants introduced at a specific, and possibly inhospitable landing site could be dispersed around the planet and introduced into more hospitable sites.
- **Issues**
  - Human missions will introduce terrestrial organisms and organics onto the surface of Mars that could hinder identification and characterization of any life forms, extinct or extant, or pre-biotic chemicals that might be present.
  - Introduction of terrestrial life may displace and destroy any indigenous life
- **Mitigation**
  - Conduct searches for life on returned samples returned from promising sites before contaminating the planet. Search as for example described in Rummel et al. 2002.
  - Apply stringent cleanliness and sterility controls on human missions
  - Avoid human landings at or near sites potentially hospitable to terrestrial life
  - better understand efficacy of dispersal of contaminants across the planet

MEPAG P-SAG on Back Contamination

MEPAG P-SAG Team

- **SKG**
  - We do not know whether Mars today has any indigenous life and if so whether that life presents any hazard to the Earth's biosphere
- **Issues**
  - Despite the best intentions and best engineering it is likely that after 500 days on the surface some uncontained martian dust and regolith will be returned to Earth with the crew.
  - While the returned materials intentionally sampled and sealed at Mars can be subject to the type of rigorous evaluation outlined in Rummel et al, 2002, the unintentionally returned materials present a more difficult problem
- **Mitigation.**
  - Return at least samples of regolith and dust to Earth for evaluation prior to the human mission to determine whether they present a hazard to the Earth's biosphere.
  - Apply stringent controls to minimize contamination of the living space

MEPAG P-SAG on Crew Protection

MEPAG P-SAG Team

- SKG's
  - We do not know whether Mars today has any indigenous life and if so whether that life presents a hazard to the crew.
  - We do not know whether the dust has any harmful properties independent of any biohazard
- Issues
  - The crew is likely to be exposed to martian dust and regolith during its 500 day stay on the surface and during the return to Earth.
  - Even if there is no life and no biohazard, the dust may have other harmful properties
- Mitigation
  - Apply stringent controls on contacts between the crew and particulates
  - Return samples of dust and regolith to Earth for evaluation prior to any human mission. The dust is of particular importance since it will be present at all sites irrespective of location.

MEPAG P-SAG on Zones of Minimum Biologic Risk

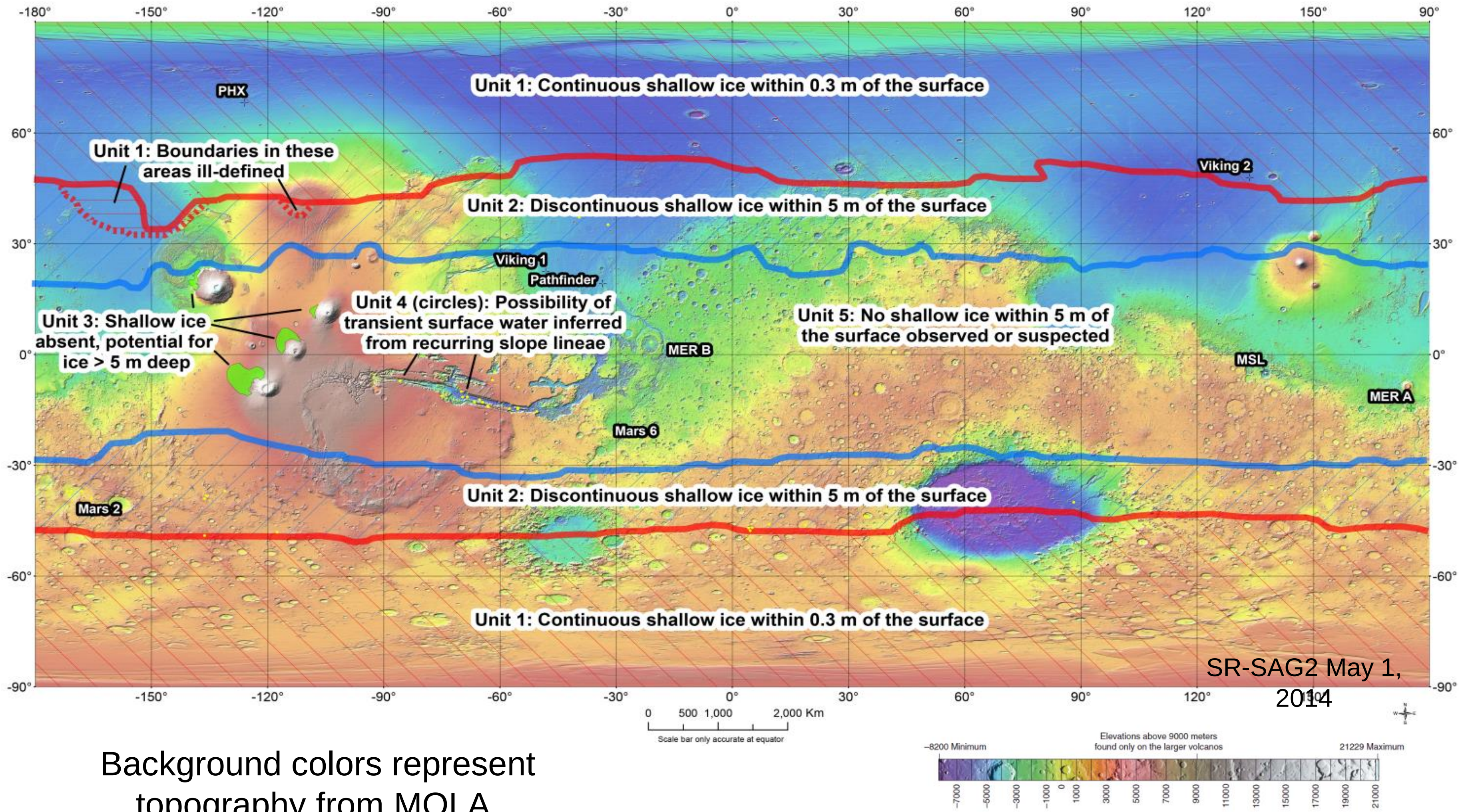
MEPAG P-SAG Team

- **SKG**
  - ‘Safe on Mars’ recommended identification of zones of minimum biological risk as sites for future human exploration. We do not yet know the location of these zones
- **Issues**
  - What criteria should be used to identify such zones
  - Given that one of the main objectives of Mars exploration is to determine if Mars has any extant life, do we want to go to a place where we are least likely to find it?
  - The desire to go to a ZMBR may be in conflict with the need to go to zones of substantial risk such as ice-rich sites for ISRU
- **Mitigation**
  - Develop a set of criteria whereby zones of both maximum and minimum risk can be identified and specifically whether in situ measurements would suffice or whether returned samples are needed to validate a site
  - As a minimum identify and avoid sites where there has been liquid water in the recent geologic past (obliquity cycle)

MEPAG SR-SAG2
Human Exploration of Mars and Special Regions

- Human exploration of Mars requires access to resources, including
  - Water
  - Oxygen
  - Protection from radiation
  - Fuel for vehicles
- These resources are available on Mars and will require access to surface or near-subsurface materials, some of which may be found in Special Regions
- Special Regions are in part defined on the availability of water, making them a potential source of water and oxygen, in addition to their science value
- Protocols need to be established so that human activities do not inadvertently affect areas designated as Special Regions or cause non-Special Regions to become Special.
  - The spread of terrestrial biological contamination could also impact life support systems, and the availability of Mars resources to human explorers.

Preliminary Map of Features of Relevance to Interpreting Special Regions on Mars

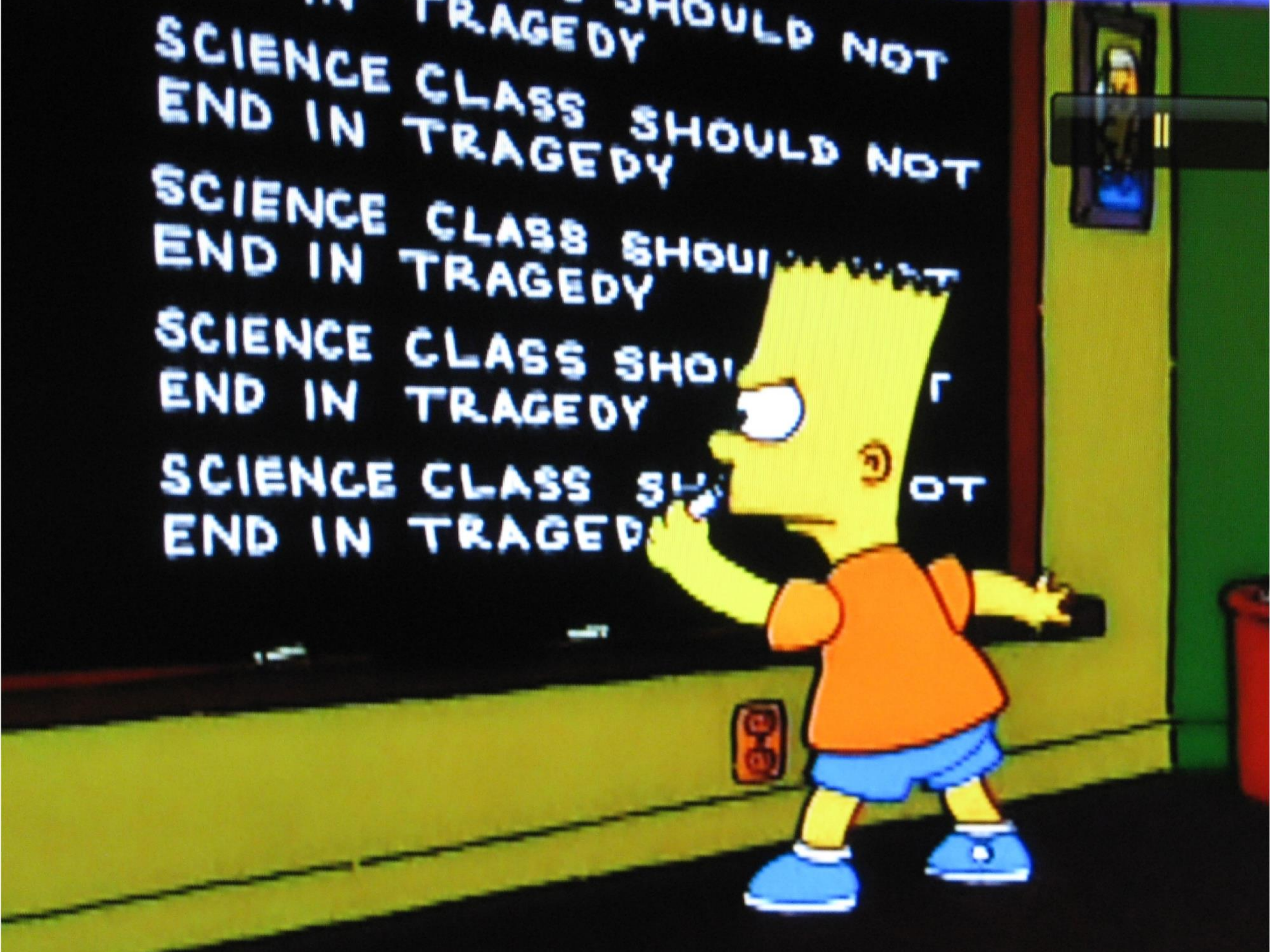


SR-SAG2 May 1, 2014

Background colors represent topography from MOLA.

Summary of Resources and Relationship to Special Regions

Resource/Activity	Sources	Special Region Concerns
H_2O Resources	Surface and near-surface	RSL sites and possibly active equatorial gullies are treated as Special Regions. Other regions may become special if ice is heated to melting.
ISRU	Atmosphere, H_2O deposits, hydrated minerals, perchlorate	Same as for H_2O Resources.
Radiation Shielding	Regolith and/or water over habitat; underground (caves/lava tubes).	Natural caves/lava tubes may be Special Regions.
Other Fuel and Power (not shown)	Atmosphere, surface materials, perchlorates, solar energy, nuclear power	May become Special if surface/subsurface ice is heated to melting.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Questions ??